laser in a process of laser drilling cooling holes in the tube wall.

Referring to Figure 1, the combustion section 10 of a gas turbine aero engine is illustrated with the adjacent engine parts omitted for clarity, that is the compressor section upstream of the combustor (to the left of the drawing in Figure 1) and the turbine section downstream of the combustion section. The combustion section comprises an annular type combustion chamber 12 positioned in an annular region 14 between a combustion chamber outer casing 16, which is part of the engine casing structure and radially outwards of the combustion chamber, and a combustion chamber inner casing 18, also part of the engine structure and positioned radially inwards of the combustion chamber 12. The inner casing 16 and outer casing 18 comprise part of the engine casing load bearing structure and the function of these components is well understood by those skilled in the art. The combustion chamber 12 is cantilevered at its downstream end from an annular array of nozzle guide vanes 20, one of which is shown in part in the drawing of Figure 1. In this arrangement the combustion chamber may be considered to be a non load bearing component in the sense that it does not support any loads other than the loads acting upon it due to the pressure differential across the walls of the combustion chamber.

The combustion chamber comprises a continuous heat shield type lining on its radially inner and outer interior surfaces. The lining comprises a series of heat resistant tiles 22 which are attached to the interior surface of the radially inner and outer walls of the combustor in a known manner. The upstream end of the combustion chamber comprises an annular end wall 24 which includes a series of circumferentially spaced apertures 26 for receiving respective air fuel injection devices 28. The radially outer wall of the combustion chamber includes at least one opening 30 for receiving the end of an ignitor 32 which passes through a corresponding aperture in the outer casing 16 on which it is secured.

The radially inner wall of the combustion chamber is provided with a plurality of circumferentially spaced apertures 34 for receiving the end part of a Helmholtz resonator damping tube 36. Each Helmholtz resonator 38 comprises a box like

resonator cavity 40 which is in flow communication with the interior of the combustion chamber through the damping tube 36 which extends radially from the resonator cavity 40 into the interior 41 of the combustor. In the drawing of Figure 1 the resonator cavity 40 extends circumferentially around part of the circumference of the combustion chamber inner casing 18 on the radially inner side thereof. The damping tube 36 extends through a respective aperture in the inner casing 18 in register with the aperture 34 in the combustion chamber inner wall. In this embodiment the damping tube has a substantially circular cross section although tubes having cross sections other than circular may be used. The Helmholtz resonator 38 is fixed to the inner casing 18 by fixing means 42 in the form of bolts, studs or the like. The resonator 38 is therefore mounted and supported independently of the combustion chamber 12. An annular sealing member 44 is provided around the outer periphery of the tube to provide a gas tight seal between the tube and the opening 34. The tube provides for limited relative axial movement of the tube with respect to the combustion chamber so that substantially no load is transferred from the resonator tube to the combustion chamber during engine operation.

As can best be seen in the cross section drawing of Figure 2, seven resonators 38 are positioned around the radially inner side of the combustion chamber inner casing 18. The resonators are arranged in two groups one including four resonators and the other group including the other three. The resonators have different circumferential dimensions such that the volume of the respective cavities 40 of the resonators is different for each resonator. This difference in cavity volume has the effect of ensuring each resonator has a different resonator frequency such that the respective resonators 38 compliment one another in the sense that collectively the resonators operate over a wide frequency band to damp pressure oscillations in the combustion chamber over substantially the entire running range of the engine. Each resonator has a particularly frequency and the resonator cavities 40 are sized such that the different resonator frequencies do not substantially overlap.

The resonator cavities are enclosed in an annular cavity 46 defined on one side by the combustion chamber inner casing 18 and along the other side by a windage shield 48,

which, in use, functions to reduce windage losses between the box type resonators 38 and the high pressure engine shaft 50 when it rotates about the engine axis 52. The windage shield 48 extends annularly around the inner casing 18 to enclose all seven resonators 38 in a streamlined manner so that windage losses are not generated by the close proximity of the resonator cavities to the engine shaft 50. A further function of the windage shield 48 is that it provides a containment structure in the event of mechanical failure of any one of the resonators 38. In the event of a mechanical failure resulting in the loss of structural integrity of a resonator, or other engine components, the windage shield acts to prevent the occurrence of secondary damage to the engine by contact with the engine shaft 50. Apertures 53 are provided in the combustion chamber inner casing 18 to allow flow communication between the annular region 14, and the annular cavity 46 defined by the windage shield 48 and the combustion chamber inner casing 18. This ensures that, during engine operation, the enclosed volume 46 of the windage shield is at the same pressure as the annular region 14 surrounding the combustion chamber, which is at higher pressure than the combustion chamber interior 41. The resultant pressure difference guarantees that, in the event of mechanical failure of any one of the resonators, air flows air into the combustion chamber 12 from the enclosed volume 46, preventing the escape of hot exhaust gasses that would severely hazard, for example, the engine shaft 50.

Referring now to Figures 3-5 which show various views of the damping tube 36 common to each of the resonators 38. As can be seen in Figure 3, the tube has a circular cross section with a plurality of circumferentially spaced cooling holes 54 formed in the tube wall. The cooling holes 54 are equally spaced around the tube circumference and are inclined with respect to respective lines tangential to the tube circumference at the hole locations. As can be seen in the drawings of Figures 4 and 5 two rows of cooling holes are provided in axially spaced relation along the length of the tube. In one embodiment the tube comprises twenty 0.5mm diameter holes in each row in a 16.0mm diameter tube. The rows of cooling holes are preferably positioned towards the open end of the tube in the combustion chamber. For instance, the first row of holes may be positioned a quarter to a third of the way along the length of the tube from the combustion chamber end, with the second row approximately halfway

along the tube.

As shown in Figure 3, in the plane perpendicular to the longitudinal axis of the tube the cooling holes 54 are angled so that they have both a radial and tangential component with respect to the circumference of the tube. Each hole is inclined at angle 45 degrees, as indicated by angle 56 in the drawing of Figure 3, with respect to the radial line 58 through the respective hole and the tube longitudinal axis. This promotes vortex flow on the interior surface of the tube when cooling air passes from the exterior region of the tube into the interior region thereof.

Referring now to Figure 4, it can also be seen that the holes are angled with respect to the longitudinal axis 60 of the tube. In the illustrated embodiment the holes have an angle of 30 degrees, indicated by angle 62 in the drawing, and are inclined towards the combustion chamber end of the tube such that the respective axis of the holes converge towards the tube axis 60. The three dimensional nature of the inclination of the holes with respect to the wall of the tube is more clearly presented in Figure 5 which shows the path of respective laser beams 64 passing through the holes and the open end of the tube during laser drilling of the holes. As the beams follow a substantially straight line the beams are indicative of the cooling hole axes.

Although aspects of the invention have been described with reference to the embodiments shown in the accompanying drawing, it is to be understood that the invention is not limited to those precise embodiments and that various changes and modifications may be effected without further inventive skill and effort. For example, other cooling hole configurations may be used including arrangements where the holes are arranged in several rows, in line, or staggered with respect to each other, with different diameters, number of holes and angles depending on the specific cooling requirements of the particular combustion chamber application. In addition, different shaped holes may be employed instead of substantially circular cross section holes. The drawings of Figures 1 and 2 show the resonators positioned on the radially inner side of the combustion chamber and mounted to the combustion chamber inner casing. In other embodiments the resonators may be located on the radially outer side of the

combustion chamber and secured to the combustion chamber outer casing 16. In the latter arrangement a windage shield would not necessarily be required.

CLAIMS

1 A combustion chamber for a gas turbine engine comprising at least one Helmholtz resonator having a resonator cavity and a damping tube in flow communication with the interior of the combustion chamber, the tube having at least one cooling hole extending through the wall thereof.

2 A combustion chamber as claimed in Claim 1 wherein a plurality of cooling holes are provided in the wall of the tube.

3 A combustion chamber as claimed in Claim 2 wherein the holes are circumferentially spaced in at least one row extending around the circumference of the tube

4 A combustion chamber as claimed in Claim 3 comprising a plurality of axially spaced circumferential rows of cooling holes

5 A combustion chamber as claimed in any of Claims 2 to 4 wherein the holes are angled with respect to the longitudinal axis of the tube.

6 A combustion chamber as claimed in Claim 5 wherein the holes are angled in a direction towards the combustion chamber end of the tube such that the respective axes of the holes converge in the direction of the combustion chamber.

7 A combustion chamber as claimed in Claim 6 wherein the angle of the holes with respect to the longitudinal axis of the tube is substantially in the range of 20 to 40 degrees.

8 A combustion chamber as claimed in Claim 7 where the said angle is substantially 30 degrees.

9 A combustion chamber as claimed in any of Claims 2 to 8 wherein the said holes are angled with respect to the tube circumference.

10 A combustion chamber as claimed in Claim 9 wherein the holes have a tangential component substantially in the range of 30 to 60 degrees with respect to the tube circumference.

11 A combustion chamber as claimed in Claim 10 wherein the angle of the holes with respect to the tube circumference is substantially 45 degrees.

12 A Helmholtz resonator for a gas turbine engine combustion chamber; the said resonator having a resonator cavity and a damping tube for flow communication with the interior of the combustion chamber, the tube having at least one cooling hole extending through the wall thereof.

13 A combustion chamber for a gas turbine engine comprising at least one Helmholtz resonator having a cavity and a damping tube in flow communication with the interior of the combustion chamber, the said at least one resonator being supported with respect to the combustion chamber independently of the combustion chamber.

14 A gas turbine engine combustion section including a combustion chamber, a combustion chamber inner casing and a combustion chamber outer casing; the said combustion chamber comprising at least one Helmholtz resonator having a cavity and a damping tube in flow communication with the interior of the combustion chamber, the said at least one resonator being supported with respect to the combustion chamber independently of the combustion chamber by the said combustion chamber inner casing or the said outer casing.

15 A combustion section as claimed in Claim 14 wherein the said at least one resonator is/are supported by the said outer casing with the said resonator(s)

positioned on the radially outer side of the combustion chamber or supported by the said inner casing with the said resonator(s) positioned on the radially inner side of the combustion chamber.

16 A combustion section as claimed in Claim 14 or Claim 15 wherein the said at least one resonator is/are supported by the said inner casing with the said resonator(s) positioned on the radially inner side of the combustion chamber and enclosed within a cavity provided between the said inner casing and a windage shield on a radially inner side of the said casing.

17 A gas turbine engine combustion section including a combustion chamber and at least a combustion chamber inner casing; the said combustion chamber comprising at least one Helmholtz resonator having a cavity and a damping tube in flow communication with the interior of the combustion chamber, the said at least one resonator being at least partially enclosed within a cavity provided between the said inner casing and a windage shield on a radially inner side of the said casing.

18 A combustion section as claimed in Claim 17 wherein the said combustor comprises a plurality of resonators, each enclosed within the said cavity provided by the said windage shield.

19 A combustion section as claimed in Claim 18 wherein the said plurality of resonators are circumferentially spaced around the combustion chamber.

20 A combustion chamber for a gas turbine engine comprising a plurality of Helmholtz resonators each having a cavity and a damping tube in flow communication with the interior of the combustion chamber, the said resonators being circumferentially spaced around the combustion chamber with the respective cavities of diametrically opposed resonators having substantially different volumes.

21 A combustion chamber as claimed in Claim 20 wherein the said resonators are circumferentially spaced around the combustion chamber with the cavities of respective resonators having successively smaller volumes.

22 A combustion chamber for a gas turbine engine comprising at least one Helmholtz resonator having a resonator cavity and a damping tube in flow communication with the interior of the combustion chamber, the said cavity having substantially similar principle dimensions.

23 A combustion chamber as claimed in Claim 22 wherein the said cavity has a substantially spherical or cubic shape.

24 A combustion chamber for a gas turbine engine of the type having a plurality of heat shield type tiles lining the interior surface of the combustion chamber; the combustion chamber comprising at least one Helmholtz resonator having a cavity and a damping tube in flow communication with the interior of the combustion chamber with the tube having an opening in the interior of the combustion chamber substantially flush with the interior surface of the tiled lining.

25 A combustion chamber substantially as hereinbefore described and/or with reference to the accompanying drawings.

26 A gas turbine engine combustion section substantially as hereinbefore described and/or with reference to the accompanying drawings.

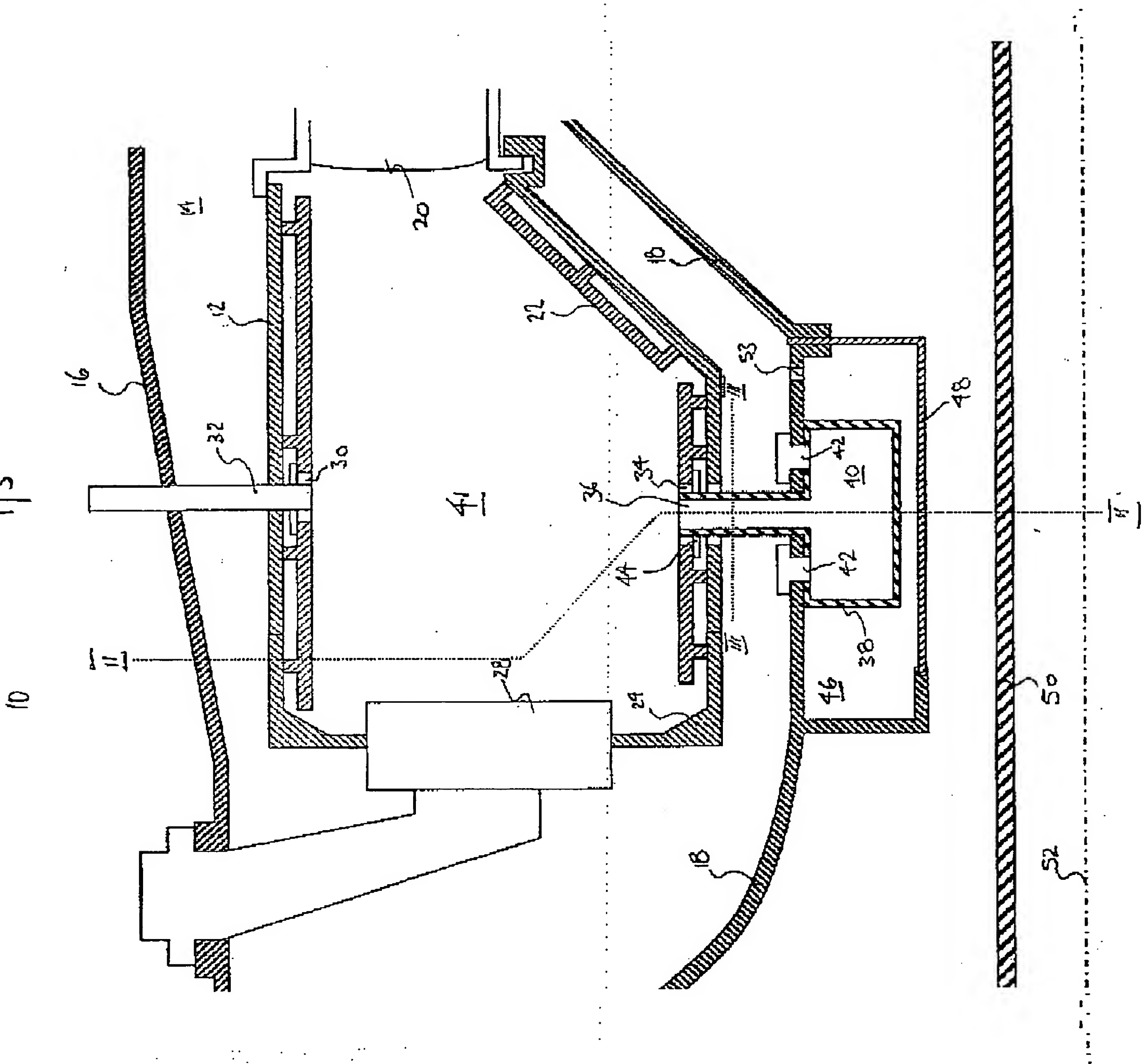
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FIG 1

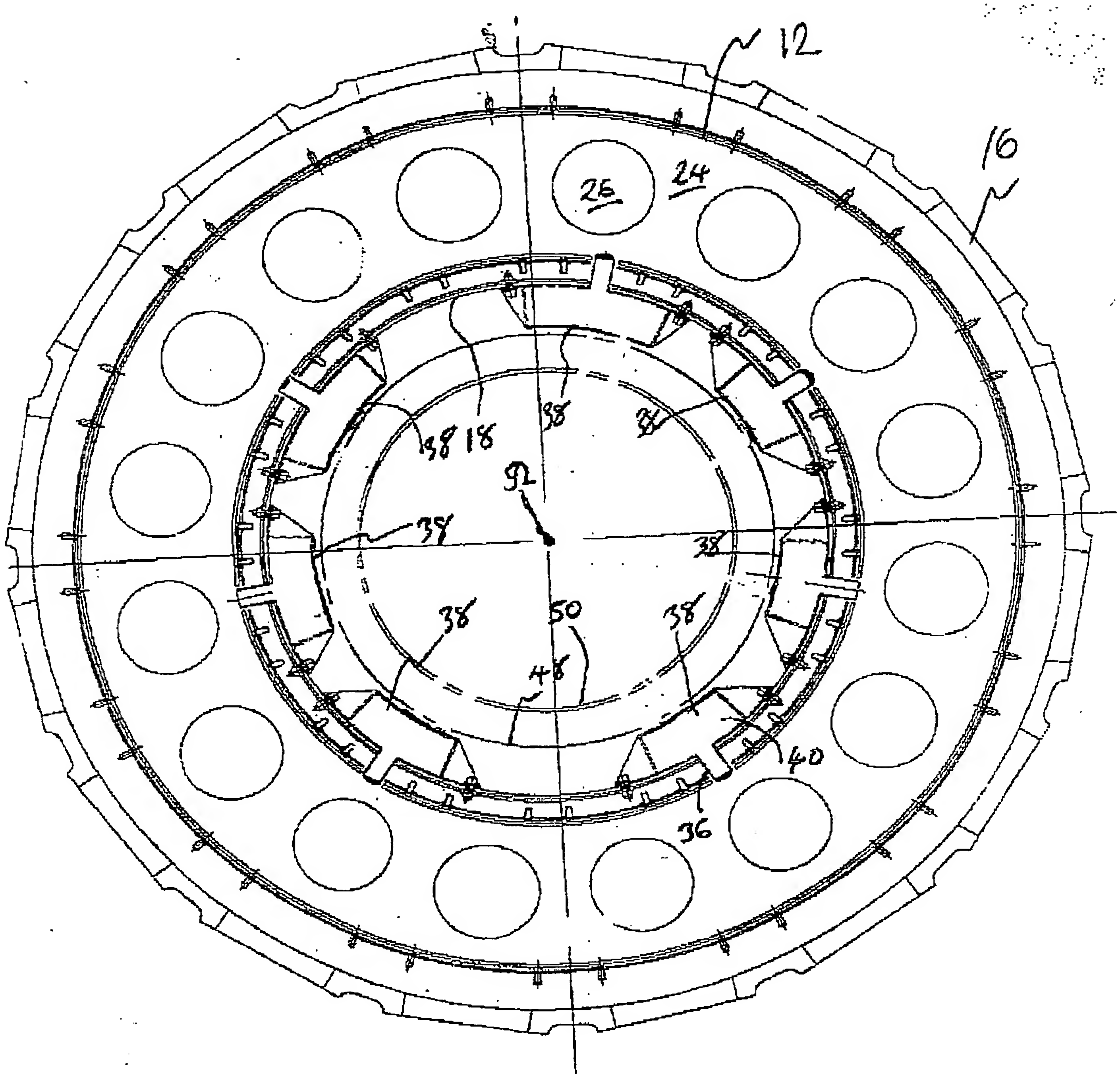

FIG. 2

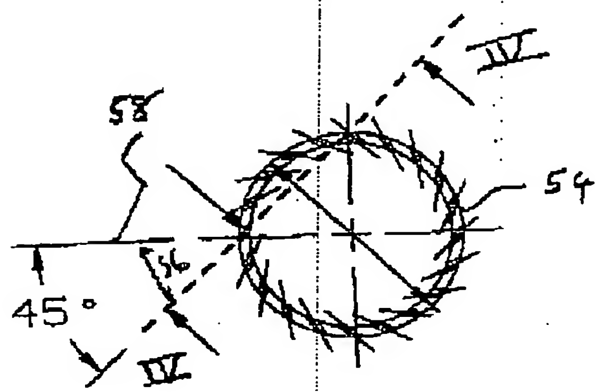

FIG 3

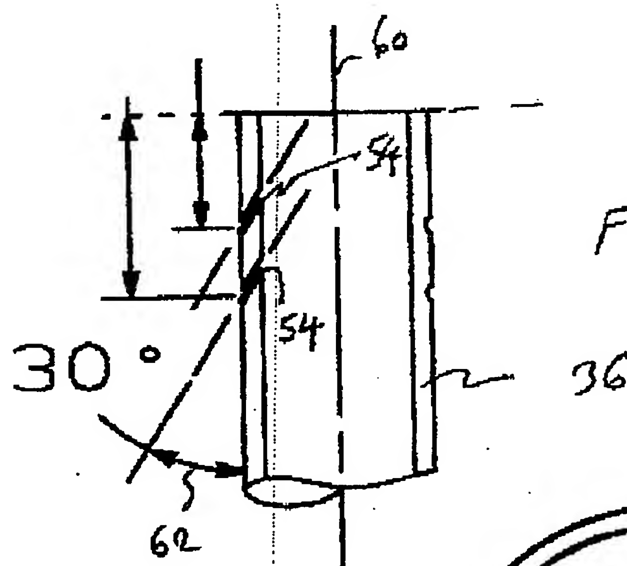

FIG 4

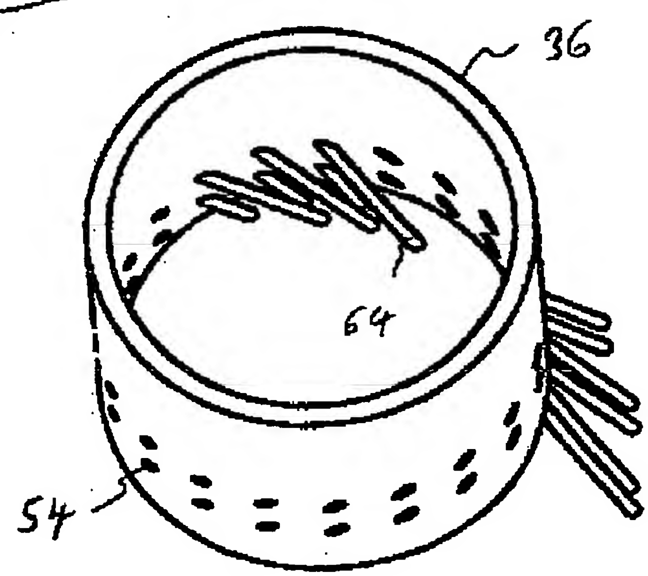

FIG 5